DETERMINATION OF A METHODOLOGY FOR CONDUCTING A COST EFFECTIVENESS ANALYSIS STUDY OF THE INTEGRATION OF LOW OBSERVABLES (LO) AND ELECTRONIC WARFARE (EW) IN AIR VEHICLE (AV) DESIGN (U)

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The advent of decreasing defense budgets coupled with acquisition reform efforts and the high cost of advanced technology applications has produced a definitive need for a methodology to assess the cost benefit of aircraft performance specifications. This methodology must be an iterative process that allows the user to perform design tradeoffs and assess their respective impacts to military utility and cost. This thesis details the approach for conducting an Analysis of Alternatives (AoA), a.k.a. Cost and Operational Effectiveness Analysis (COEA), study to assess the cost-performance tradeoffs of applying Low Observable (LO) technology and Electronic Warfare (EW), either exclusively or mutually, to an aircraft design. The methodology recommends the use of engagement level models and simulations (M&S) coupled with mission level M&S in the absence of a single integrated M&S product. The engagement level analysis is necessary to support high fidelity data requirements that are used by the mission level program to gather relevant measures of effectiveness (MOE) required for the mission effectiveness evaluation. These MOE's are then integrated with corresponding cost data in an effort to examine cost-performance characteristics. Iterative performance modifications can be similarly evaluated in an effort to establish trends, which will assist the user in assessing cost-performance tradeoffs.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Other (Low Observables, Electronic Warfare, Electronic Counter-Measures)

KEYWORDS: Low Observables, Radar Cross Section Reduction, RCS, Electronic Counter-Measures, ECM, Modeling and Simulation, M&S, Mission Level Modeling and Simulation, Enhanced Surface-To-Air Missile Simulation, ESAMS

THE ANALYSIS OF COMPONENTS, DESIGNS, AND OPERATION FOR ELECTRIC PROPULSION AND INTEGRATED ELECTRICAL SYSTEM

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The surface combatant of the 21st century will be designed to support a myriad of tasks requiring greater flexibility and endurance while keeping construction, maintenance and operating costs to a minimum. As a result the design of a surface combatant will depart from today's standards and philosophies. One option is
the use of an electric propulsion system that can be integrated with the other ship's electrical loads. Electric propulsion operating with an Integrated Electrical System has many advantages that will fulfill the requirements of future surface combatants.

This study provides the historical background, the supporting issues, components, and architecture of electric propulsion systems and the integrated electrical system. Technical information on various component types and issues that influence the design considerations of an electric propulsion system and integrated electrical system to meet the requirements of a surface combatant are addressed. The areas of study are prime movers, generators, frequency converters, motors, ship's service electrical distribution, auxiliary electrical loads, and system control.

The designer and operator of the surface combatant of the 21st Century can better understand the application of an electric propulsion system and an integrated electrical system from the accrued information on components, system architecture, and system control herein.

DoD KEY TECHNOLOGY AREA: Surface/Under Surface Vehicles - Ships and Watercraft

KEYWORDS: Electric Propulsion, Ship's Propulsion, Prime Movers, Generators, Synchroconverter, Cycloconverter, Pulse Width Modulation, Synchronous Motors, Synchronous Machine Ship's Service Electrical System, Integrated Electrical System, Ship's Service Distribution System, Ship's Service Electric Generator, Six-Pulse, 12-Pulse, DC ZEDS, Electro-Magnetic Aircraft Launching System, Pulse Energy Weapons, Power Electronic Devices

GLOBAL BROADCAST SYSTEM REACH BACK VIA ULTRA HIGH FREQUENCY DEMAND ASSIGNED MULTIPLE ACCESS SATELLITE COMMUNICATIONS

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The U.S. military requires a reliable, high-speed, multimedia capable system to disseminate information that cannot be efficiently distributed over existing low data rate channels. The Global Broadcast System (GBS) is being developed to meet this requirement. The cornerstones of the GBS simplex broadcast are the premises of smart push and user pull. An integral part of the user pull is the reach back channel. The reach back channel allows users to specify the information they need broadcast and tailor the information to meet their mission needs. Ultra high frequency (UHF) demand assigned multiple access (DAMA) satellite communications are the most widely available long haul communication systems available to members of the armed services and as such are a prime candidate to provide a reach back path for GBS. In order to fully utilize UHF DAMA as a reach back channel for data communications a number of interface requirements must be met. The problems of using UHF DAMA are discussed and recommendations are made for the GBS Phase Two systems so they might support the use of UHF DAMA as a reach back channel. This thesis shows that UHF DAMA is a viable reach back channel, however there are factors which could improve the efficiency.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Global Broadcast System, Reach Back, Ultra High Frequency Demand Assigned Multiple Access

DESIGN OF AN 8 x 8 NON-BLOCKING CROSSPOINT SWITCH IN GaAs TWO-PHASE DYNAMIC FET LOGIC

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Computer resources on military and telecommunications satellites are being over-tasked more than ever before, and the increasing shift to onboard signal processing will only compound the problem in the future. Space-based multiprocessor computer systems linked by high speed interconnect networks offer one possible solution to this ever-expanding problem. Fallium arsenide (GaAs) integrated circuits using metal-semiconductor field effect transistors (MESFSTs) offer very high speed operations, reduced power consumption, and inherent radiation tolerance, which make them ideally suited to the harsh space environment.

The design, simulation and layout of an 8 x 8 non-blocking crosspoint switch implemented in GaSa two-phase dynamic FET logic (TDFL) is presented in this thesis. The design of the TDFL crosspoint switch design that uses GaAs direct-coupled FET logic (DCFL). Design specifics of working with GaAs are presented first, followed by detailed descriptions of the DCFL and TDFL crosspoint switches, and finally, an analysis of the advantages and disadvantages of dynamic logic over static logic is presented.

The TDFL crosspoint switch presented here could easily be modified to serve as a one gigabit per second serial interconnect for future space-based multiprocessor computer systems.

KEYWORDS: GaAs, Gallium Arsenide, Crosspoint Switch, TDFL, Two-phase Dynamic FET Logic

DoD KEY TECHNOLOGY AREAS: Electronics, Computing and Software, Command, Control, and Communications

TRANSIENT LOCALIZATION IN SHALLOW WATER ENVIRONMENTS

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In this work, the robustness of a simple, Bartlett-type processor based on matching broadband signal autocorrelation functions is investigated. Measures of robustness to be examined include the size of the localization footprint on the ambiguity surface and the peak-to-sidelobe levels in the presence of environmental mismatch and noise. A full-wave PE model is used to produce broadband replicas. Both model-generated synthetic signals, which provide baseline results, and measured pulses in a shallow water environment are analyzed.

This work suggests that environmental mismatch has a more significant effect on the localization performance than noise. It also suggests that, as long as the noise level is not higher than the signal level, the localization performance will not be significantly affected. This is to be expected, since for white noise the majority of the influence on the autocorrelation function occurs at zero lag which has been removed in the localization algorithms. It is also shown that the autocorrelation matching in the time-domain is generally more useful for smaller bandwidths at low frequencies, which has been observed in previous work, whereas the autocorrelation matching in the frequency-domain is better suited for larger bandwidths and higher frequencies.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation
KEYWORDS: Autocorrelation Matching, Transient Localization, Shallow Water

MERGEFORMAT AUTOMATIC EXTRACTION OF THREAT SIMULATOR CRITICAL PARAMETERS VERSION 3.0 (U)

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Anti-ship cruise missiles (ASCMs) continue to be a poignant threat to the surface combatants of the U.S. Navy. OPNAV 913 directs the Effectiveness of Navy Electronic Warfare Systems (ENEWS) program to develop hardware-in-the-loop (HIL) simulators to support the research, development, test and evaluation of the most critical threats of interest. To ensure that the ASCM simulator accurately represents the threat missile, OPNAV 913 has recently established the Navy Unique ASCM Simulator Validation Working Group. One part of the validation process is to run the ASCM simulator through a battery of anechoic chamber characterization tests in order to determine the simulator's performance. The ASCM simulator's Electronic Warfare Integrated Reprogrammable Database (EWIRDB) parameters can easily be extracted from the characterization results using computer algorithms that automatically analyze the data. Comparing the corresponding parameters with the EWIRDB intelligence entries then provides one technique for measuring the performance of the ASCM simulator. This thesis describes a novel set of algorithms that extract 32 new EWIRDB parameters from characterization data, of

which 29 are related to pulse repetition interval (PRI) characteristics, two are related to velocity memory and one is related to azimuth accuracy. FFT and autocorrelation function techniques to compute PRI mode parameters with periodic and staggered components are developed. Also, a graphical user interface (GUI) in a Matlab environment and a modular architecture allowing for straightforward software development and maintenance are discussed. The performance of a number of significant threats are numerically evaluated as a function of the test results.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Modeling and Simulation, Computing and Software

KEYWORDS: ASCM Simulators, Automatic Extraction of Threat Simulator Critical Parameters, GUI, Algorithms, EWIRDB Parameters

CONSTRUCTION AND MEASUREMENT OF AN ACTIVELY MODE-LOCKED SIGMA LASER

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The direct digitization of microwave signals of interest would allow rapid computer processing and analysis. Current analog-to-digital converters (ADCs) are bandwidth limited and electronic warfare systems must down-convert the signal before digitization causing a loss of information. Optical ADCs can directly digitize frequencies greater than 10 GHz using wideband integrated optical interferometers (folding ADCs). A critical component of the optical folding ADC is the pulsed laser used for sampling the wideband signal. The amplitude-modulated pulses become the discrete samples of the analog signal. Limiting factors in an optical ADC are the pulsewidth, the pulse rate, and the jitter noise of the optical pulse train. Mode-locked lasers provide pulse rates and pulsewidths suitable for high bandwidth applications.

In this thesis a mode-locked sigma laser was constructed using fiber-optic, electro-optic, and microwave components. The theory of mode-locking, laser construction, output measurements, and sampling applications are discussed in detail. The mode-locked sigma laser demonstrated a pulse repetition frequency of 16 GHz, pulsewidth of 7.2 picoseconds, amplitude noise less than 1%, temporal jitter of 386 femtoseconds, and the ability to be harmonically mode-locked at twice the modulation frequency using only 200 mW of diode pump power in the optical amplifier. The analysis shows that this laser can be used in an optical ADC to sample a 6.44 GHz signal at 7 bits, 3.22 GHz at 8 bits, or 1.61 GHz at 9 bits of resolution.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Other (Photonics)

KEYWORDS: Mode-Locked Laser, Sigma Laser, Erbium-Doped Fiber Amplifier, Optical Sampling, Analog-to-Digital Conversion, Amplitude Noise, Phase Noise, Temporal Jitter Noise, Timing Uncertainty

DENOISING OF ACOUSTIC SIGNALS USING WAVELET/WIENER BASED TECHNIQUES

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This thesis investigates the use of combined Wavelet decomposition and Wiener filtering for the removal of noise from underwater acoustic signals. Several Wavelet/Wiener based denoising techniques are presented and their performances

compared. Performances of the denoising algorithms are compared to those of Wiener filter and wavelet thresholding implementation and demonstrate that Wavelet/Wiener based methods are also a viable tool for the denoising of acoustic data under more restrictive conditions.

DoD KEY TECHNOLOGY AREAS: Sensors, Electronic Warfare

KEYWORDS: Acoustic Signals, Wavelets, Wiener Filter, Denoising, Aliasing

SINGLE-FREQUENCY MEASUREMENTS USING UNDERSAMPLING METHODS

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The objective of this study is to verify the Symmetrical Number System (SNS) undersampling receiver architecture using software and to investigate implementation issues using digital signal processing (DSP) hardware. In the software design, a MATLAB program is written to determine a single sinusoidal input frequency using this receiver architecture. Each channel of the SNS undersampling receiver consists of a low speed ADC, a discrete Fourier transform followed by a constant threshold device to detect the signal's frequency bin. The detected frequency bins are then recombined in an SNS-to-decimal algorithm to recover the frequency of the signal. Error rate performance in a Gaussian noise environment at the input stage is evaluated. In the hardware design, a sinusoidal waveform is digitized, discrete Fourier transformed and converted from the SNS format to a decimal value using a single channel digital signal processor. Implementation difficulties and design issues are discussed.

DoD KEY TECHNOLOGY AREA: Electronic Warfare

KEYWORDS: Symmetrical Number System, Symmetrical Folding, Undersampling, Discrete Fourier Transform

ARCHITECTURAL DEVELOPMENT AND PERFORMANCE ANALYSIS OF A PRIMARY DATA CACHE WITH READ MISS ADDRESS PREDICTION CAPABILITY

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This work is part of an ongoing effort to bridge the cycle-time gap between high-speed processing units and lower-speed main memories through the use of memory hierarchies. Cache memory exploits the principle of locality by providing a small, fast memory between the processor and the main memory. The Predictive Read Cache (PRC) further improves the overall memory hierarchy performance by tracking the data read miss patterns of memory accesses, developing a prediction for the next access and prefetching the data into the faster cache memory. The PRC has been proven to significantly improve system performance when acting as a second-level cache. The purpose of this thesis is to simulate the effectiveness of the PRC as a first-level cache in the memory hierarchy using the same simulator developed to prove the effectiveness of the PRC as a second-level cache.

DoD KEY TECHNOLOGY AREA: Computing and Software

KEYWORDS: Predictive Read Cache, Address Prediction, Memory Bandwidth, Memory Latency, Cache Memory, Memory Systems

SINGLE-EVENT ANALYSIS OF AlInAs/GaInAs/InP HETEROJUNCTION BIPOLAR TRANSISTORS

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For many of today's spaceflight programs, spacecraft and spacecraft designers are being pushed to utilize enabling and emerging technology in order to meet performance constraints in small-volume and low-power, low-cost spacecraft. These newer technologies must be evaluated to meet the performance requirements of spacecraft, especially for the smaller, low-cost satellite programs. AlInAs/GaInAs heterojunction bipolar transistors (HBTs) grown on InP substrates are emerging as an alternative HBT technology to the more widely used GaAlAs/GaAs HBTs for high performance and low-power integrated-circuit applications. However, these technologies may be vulnerable to single-event effects in the space environment. Recent testing at the University of Michigan at Ann Arbor has shown that HBT circuits are sensitive to single-event effects (SEEs). This thesis examines the effects of cosmic ray induced charge collection on AlInAs/GaInAs HBT by utilizing Silvaco's Virtual Wafer Fabrication software to design and simulate electrical properties of transistors. Two-dimensional computer simulations were performed to determine why the InP HBT is sensitive to charge collection events; whether charge collection is occurring across base-collector or base-emitter junctions; and what is causing the radiation sensitivity. Computer simulations are performed using Atlas® device simulation software created by Silvaco International, Inc®. The simulation results are compared to actual SEU test data.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Manufacturing Science and Technology, Electronics

KEYWORDS: Heterojunction Bipolar Transistor, Single-Event Upsets, Indium Phosphide, Aluminum Indium Arsenide, Gallium Indium Arsenide

ANALYSIS OF FINITE PHASED ARRAYS ON SHAPED GROUND PLANES

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The objective of this thesis is to evaluate the performance of an array antenna when this is installed on an complex structure, such as those that have unusual edge contour, curved surfaces, and mixed material composition. A dipole is used as the basic array element to study the effect of various changes in the array design parameters on the gain and sidelobe level. Data is generated using a computational electromagnetics code based on the method of moments. Among the issues addressed are the curvature of the array ground plane and shaping the ground plane edges to reduce wide-angle sidelobes.

KEYWORDS: Arrays, Radiation Pattern

DoD KEY TECHNOLOGY AREA: Electronics

FEASIBILITY ANALYSIS FOR A SUBMARINE WIRELESS COMPUTER NETWORK USING COMMERCIAL-OFF-THE-SHELF COMPONENTS

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This thesis investigates the feasibility of deploying wireless local area networks (WLANs) onboard submarines. Installing wireless networks on submarines is intended to improve the productivity of the crew by leveraging the superior connectivity and data processing capabilities of commercial-off-the-shelf (COTS) wireless networking technologies. Areas specifically targeted for improvement are damage control communications and watchstander log taking.

In this thesis, the effects on wireless communications of the submarine's mostly metallic construction are examined along with potential mitigation methods. The overall requirements and specifications for a submarine wireless network are also derived. These constraints are then matched against the capabilities of existing commercial products in the mobile computing and wireless networking industries. Finally, a proof of concept system is developed and evaluated in both laboratory and submarine environments. Testing results demonstrate that a low-cost, high-performance WLAN for use in submarines is achievable using existing technologies. Additionally, recommendations are provided as to which evolving technologies have the most promise for future system improvements. This thesis work is the first part of an ongoing project that is tasked to specify, design, prototype, and test a wireless local area network for installation in the New Attack Submarine (NSSN).

DoD KEY TECHNOLOGY AREAS: Computing and Software, Command, Control, and Communications, Other (Wireless Communications)

KEYWORDS: Wireless Local Area Networks, Spread Spectrum, PDAs, Handheld Computers

AN ANALYSIS OF LIMITATIONS IN ACTIVE CANCELLATION OF RADAR SIGNALS

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Acoustic noise suppression has been achieved by rebroadcasting a phase-inverted copy of an incident signal, such that the two signals cancel. The same effect applies in theory to electromagnetic signals, allowing the cancellation of radar signals. This effect would supplement existing "stealth" technologies. The electromagnetic equivalence theorem provides for a straightforward theoretical analysis, and several numerical analyses demonstrate cancellation on simple wire models. The limitations of the cancellation are covered with respect to bandwidth, canceler spacing, and two canceler unit failure (error) modes. Sucessful cancellation is demonstrated for two canceler densities up to approximately 50 MHz, and a significant reduction in canceler effectiveness results when the two failure modes are tested.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Electronic Warfare, Sensors

KEYWORDS: Radar, Electromagnetic Field Cancellation, Radar Cancellation, Scattering Analysis

FREQUENCY DEPENDENCE OF SINGLE EVENT UPSETS IN GALLIUM ARSENIDE METAL SEMI-CONDUCTOR FIELD EFFECT TRANSISTORS

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Single event upsets (SEUs) are the result of high-energy particles passing through transistors in electronic circuits, causing errors in flip-flops and memory circuits. Gallium Arsenide (GaAs) Metal Semiconductor Field Effect Transistors (MESFETs) are desirable for space systems due to their lower power consumption at higher frequencies. However, they are more prone to errors from high-energy particles in the space environment. The goal of this research was to explore the temporal aspects of SEUs in GaAs MESFETs to determine the causes of variation in upset rates with frequency. By performing two-dimensional simulations of inverter circuits, the fundamental building blocks of electronic storage elements, a more accurate simulation of SEUs is possible, providing greater insight into the circuit response to particle strikes as transient signals are applied. This thesis develops doping profiles to match electrical characteristics of both conventional and radiation-tolerant MESFETs using Low-Temperature grown GaAs (LTGaAs). Techniques are developed to incorporate multiple transistors in 2-D simulations, more accurately replicating circuit responses. Finally, it is shown that the response to SEUs depends on the timing of the particle strike in relation to the signal transient, resulting in a varying error rate as a function of circuit frequency.

DoD KEY TECHNOLOGY AREAS: Electronics, Modeling and Simulation

KEYWORDS: GaAs, MESFET, SEU, Transient, Frequency Dependence

CLASSIFICATION OF UNDERWATER SIGNALS USING WAVELET-BASED DECOMPOSITIONS

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This thesis investigates the application of wavelet decompositions to classification applications. Two feature extraction tools are considered: Local Discriminant Bases (LDB) scheme and Power method. Several dimension reduction schemes including a newly proposed one called the Mean Separator Neural Network (MSNN) are discussed. Two types of classifiers are investigated and compared: Classification Trees (CT) and Back-Propagation Neural Network (BPNN). Classification experiments conducted on synthetic and real-world underwater signals show that: 1) the power feature extraction method is more robust to time synchronization issues than the LDB scheme is; 2) the MSNN scheme is a successful dimension reduction scheme that may be used with both LDB and Power feature extraction methods; and 3) the BPNN is a more powerful classifier than CT as it has fewer constraints than CT in partitioning the feature input space.

DoD KEY TECHNOLOGY AREAS: Sensors, Electronic Warfare

KEYWORDS: Classification, Wavelet Decomposition, Local Discriminant Bases (LDB), Dimension Reduction, Classification Trees (CT), Back-Propagation Neural Network (BPNN), BCM

OBJECT RECOGNITION USING 2D SENSORS AND AUTONOMOUS VEHICLE NAVIGATION ISSUES

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This research deals with the problem of extracting features from an image using wavelets and then using these features to recognize objects present in the image. This technique is applied to recognition of Unexploded Ordnance (UXO) objects. However, the concepts described here can be extended to recognition of other objects such as ships, missiles and aircrafts. This work is performed as part of an ongoing effort to develop an autonomous vehicle capable of detecting UXOs.

KEYWORDS: Image Recognition, Unexploded Ordnance, Wavelets, Neural Networks, Motion Control

DoD KEY TECHNOLOGY AREAS: Computing and Software, Electronic Warfare, Modeling and Simulation, Ground Vehicles

USING THE PEBB UNIVERSAL CONTROLLER TO MODIFY CONTROL ALGORITHMS FOR DC-TO-DC CONVERTERS AND IMPLEMENT CLOSED-LOOP CONTROL OF ARCP INVERTERS

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The objective of this thesis is two-fold. The first goal is to expand the operational capabilities of the Ship's Service Converter Module control algorithm for a DC-to-DC converter using the Universal Controller. The second goal is to investigate the use of the Universal Controller to implement a closed-loop control algorithm for an Auxiliary Resonant Commutated Pole (ARCP) power inverter. These power electronic devices are central to the development of a DC Zonal Electric Distribution System (DC ZEDS) that is scheduled for application in the twenty-first century surface combatant (SC-21). The development of appropriate control algorithms is a key element to this design process. The Universal Controller is a digital controller that was developed by personnel at the Naval Surface Warfare Center (NSWC), Annapolis, Maryland. The basic operation of the Universal Controller and the Texas Instrument TMS320C30 microprocessor architecture are described, with emphasis placed on the system control algorithms.

Previous studies have encoded and successfully tested a closed-loop control algorithm for a DC-to-DC converter. In this research endeavor, this control algorithm is expanded to include various protection circuits and a Master/Slave paralleling scheme. Finally, a closed-loop control algorithm for the ARCP inverter is encoded and recommendations for future research are outlined.

DoD KEY TECHNOLOGY AREAS: Surface/Under Surface Vehicles - Ships and Watercraft, Computing and Software

KEYWORDS: DC-to-DC Buck Converter, Auxiliary Resonant Commutated Pole Inverter, Universal Controller, Closed-Loop Control of Power Inverters, Texas Instruments TMS320C30

ACOUSTIC NOISE REMOVAL BY COMBINING WIENER AND WAVELET FILTERING TECHNIQUES

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This thesis investigates the application of Wiener filtering and wavelet techniques for the removal of noise from underwater acoustic signals. Both FIR and hR Wiener filters are applied in separate methods which involve the filtering of wavelet coefficients which have been produced through a discrete wavelet decomposition of the acoustic signal. The effectiveness of the noise removal methods is evaluated by applying them to simulated data. The combined Wiener wavelet filtering methods are compared to traditional denoising techniques which include Wiener filtering and wavelet thresholding methods.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors

KEYWORDS: Wavelet Analysis, Wiener Filtering, Denoising, Acoustic Signals

THE MACH-ZEHNDER COUPLER

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This thesis is the second in a series which investigates the possibility of creating a code-shift-keying (CSK) optical receiver using single-mode 2x2 couplers and fiber optical delay lines to construct Mach-Zehnder couplers which comprise the main building block of the CSK receiver. There were two main goals of this thesis research. The first was to investigate design and construction modifications which would lower the system loss of a previously designed Mach-Zehnder coupler. As a result of this research, the system loss was reduced from 10.5 dB to 3.3 dB by changing the design to eliminate an unnecessary stage and by replacing several mechanical connections with fusion splices. The second goal was to find a method to measure the inherent phase shift of a 2x2 fiber optical coupler. Two separate methods were developed and implemented, and a third previously developed method was used to verify the results. All three methods provided experimental values between 145∞ and 149∞. This thesis develops the theory that explains the discrepancy between the measured values and the ideal value of 180∞ for the inherent phase shift

KEYWORDS: Fiber Optic Receiver, Mach-Zehnder Coupler, Interferometry

DoD KEY TECHNOLOGY AREAS: Electronics, Sensors, Command, Control, and Communications

COMPUTER MODELING OF CAPTIVE-CARRY MISSILE SIMULATOR EXPERIMENTS

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The increasing number, diversity and sophistication of the anti-ship cruise missiles around the world in the past thirty years have led to sophisticated countermeasures. The Naval Research Laboratory has developed hardware-in-the-loop (HIL) missile simulator technology to assess the effectiveness of electronic attack (EA) countermeasures. These simulators appear in two basic configurations: the closed-loop in an anechoic chamber and the open-loop captive-carry on board a P-3 aircraft.

The objective of this thesis was to develop a comprehensive Simulink© model representing the two HIL missile simulator configurations. These models were then used to study the influence of each parameter on EA effectiveness, as measured by missile miss distance.

The development of this model now makes it possible to compare the seeker responses of the two configurations as well as to have an inexpensive way to test new approaches to combine the closed-loop missile dynamics with the open-loop environment information to obtain more accurate EA effectiveness measurements.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Anti-Ship Cruise Missiles, Electronic Attack (EA), Hardware-in-the-Loop, Missile, Simulations, ASCM Digital Model, EA Effectiveness, Miss Distance

OPTIMUM SYMMETRICAL NUMBER SYSTEM PHASE SAMPLED DIRECTION FINDING ANTENNA ARCHITECTURES

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A new interferometer direction finding array architecture based on the optimum symmetrical number system (OSNS) is presented. OSNS arrays are capable of unambiguous high-resolution direction finding with as few as three elements, with multiple baseline options. The OSNS DF antenna architecture being investigated uses the OSNS to decompose the analog spatial filtering operation into a number of parallel sub-operations (moduli) that are of smaller complexity. One two-element interferometer is used for each sub-operation and only requires a precision in accordance with its modulus. A much higher spatial resolution is achieved after the sub-operations are recombined. By incorporating the OSNS concept, the dynamic range of a specific configuration of antenna element spacings and comparator arrangements can be analyzed exactly. In this thesis, the OSNS DF antenna concept was demonstrated experimentally, by designing, fabricating and measuring the performance of a three-element array at 8.5 GHz. These three elements are grouped into two pairs (channels) according to the set of relatively prime moduli ($in_1 = 6$, $in_2 = 11$). A mixer is used to determine the phase difference between each pair of elements. The output voltage from the mixer in each channel is a symmetrical folding waveform that is DC biased and amplified using a summing amplifier. The output voltage of the amplifier is amplitude analyzed using a small comparator ladder. An EEPROM is used to recombine the results of these low precision channels to yield the high resolution direction of arrival (DOA). Simulated and experimental results are presented and compared.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Direction Finding Antennas, Array Antennas, Rectangular Aperture Antennas, Open-ended Waveguides, Optimum Symmetrical Number System (OSNS), Weighted Summing Amplifier, Analog-to-Digital Converter, Comparator ladder.

FEATURE-BASED LOCALIZATION IN SONAR-EQUIPPED AUTONOMOUS MOBILE ROBOTS THROUGH HOUGH TRANSFORM AND UNSUPERVISED LEARNING NETWORK

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Second Reader: Robert G. Hutchins, Department of Electrical and Computer Engineering

As we approach the new millennium, robots are playing an increasingly important role in our everyday lives. Robotics has evolved in industrial and military applications, and unmanned space exploration promises the continued development of ever-more-complex robots. Over the past few decades, research has focused on the development of autonomous mobile robots—robots that can move about without human supervision. This brings with it several problems, however, specifically the problem of localization. How can the robot determine its own position and orientation relative to the environment around it?

Various methods of localization in mobile robots have been explored. Most of these methods, however, assume some a priori knowledge of the environment, or that the robot will have access to navigation beacons or Global Positioning Satellites. In this thesis, the foundations for feature-based localization are explored. An algorithm involving the Hough transform of range data and a neural network is developed, which enables the robot to find an unspecified number of wall-like features in its vicinity and determine the range and orientation of these walls relative to itself. Computation times are shown to be quite reasonable, and the algorithm is applied in both simulated and realworld indoor environments.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Autonomous Mobile Robots, Hough Transform, Localization, Nomad Scout Mobile Robot, Competitive Neural Networks, Data Clustering

COMMUNICATIONS VULNERABILITY ANALYSIS OF FINANCIAL TELECOMMUNICATIONS

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Master of Science in Systems Engineering-September 1998
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Second Reader: Vicente Garcia, National Security Agency Cryptologic Chair

The American defense forces, national intelligence, and law enforcement agencies are challenged with meeting high operational demands with a finite set of resources. This thesis proposes a new Information Operations tool that focuses upon using computer network analysis. Using the OPNET Modeling and Simulation software, developed, by MIL3, Inc. to demonstrate how nation states and non-governmental organizations who condone and support the sale of illegal narcotics use computers and electronic media to communicate, an Information Operations/Warfare plan can be developed to defeat its use. Furthermore, this thesis' centers its research on how to remove the incentive, money, from drug dealer's coffers; thus, making the cultivation and sale of illegal narcotics a zero sum game.

This thesis concentrates on one nation in particular, country X, to create a baseline model of its electronic financial transactions. Once a model of a nation, who sponsors criminals and terrorist to operate within its borders, is created then

this model can be tailored to fit any other nation. The strategy behind this research centers on country X's critical communications nodes and how to manipulate the nodes to serve our purpose vice their original intent.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Electronics, Electronic Warfare, Modeling and Simulation

KEYWORDS: Telecommunications, OPNET, Money Laundering

AN INTEGRATED INS/GPS NAVIGATION SYSTEM FOR SMALL AUVS USING AN ASYNCHRONOUS KALMAN FILTER

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Second Reader: Eric R. Bachmann, Department of Computer Science

A Small AUV Navigation System (SANS) is being developed at the Naval Postgraduate School. The SANS is an integrated INS/GPS navigation system composed of low-cost, small-size components. It is designed to demonstrate the feasibility of using a low-cost Inertial Measurement Unit (IMU) to navigate between intermittent GPS fixes.

This thesis presents recent improvements to the SANS hardware and software. The 486-based ESP computer used in the previous version of SANS is now replaced by an AMID 586DX133 based PC/104 computer to provide more computing power, reliability and compatibility with PC/104 industrial standards. The previous SANS navigation filter consisting of a complementary constant gain filter is now aided by an asynchronous Kalman filter. This navigation filter has six states for orientation estimation (constant gain) and eight states for position estimation (Kalman filtered). Low-frequency DGPS noise is explicitly modeled based on an experimentally obtained autocorrelation function. Ocean currents are also modeled as a low-frequency random process. The asynchronous nature of DGPS measurements resulting from AUV submergence or wave splash on the DGPS antennas is also taken into account by adopting an asynchronous Kalman filter as the basis for the SANS software. Matlab simulation studies of the asynchronous filter have been conducted and results documented in this thesis.

DoD KEY TECHNOLOGY AREA: Electronics, Sensor

KEYWORDS: INS, GPS, AUV, Navigation, Kalman Filter

IMPLEMENTATION OF A MULTIPLE ROBOT FRONTIER-BASED EXPLORATION SYSTEM AS A TESTBED FOR BATTLEFIELD RECONNAISSANCE SUPPORT

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Future military battlefields will see smaller forces responsible for ever increasing geographical areas. In addition, future conflicts will occur more often in urban or built-up areas. Both of these trends argue for some type of augmentation for initial reconnaissance, continued observation, and control of lines of communication and other key terrain features. Multisensor systems, mounted on a variety of robotic platforms, can provide this type of battlefield support where it is needed most. However, before costly decisions concerning the details of such systems can be made, basic research needs to be conducted regarding their most effective composition and utilization.

Prior to this time all multiple robot studies at this institution had only taken place in simulated environments. This thesis implements a real-world multiple robot system that uses a technique known as frontier-based exploration to explore and

map a laboratory or office environment. In doing so, many previously hidden aspects of multiple robot systems, unnoticeable in simulation-only studies, become evident. The results developed here are compared to results obtained elsewhere involving other robotic platforms. This research lays the foundation for future research involving multiple robots interacting as a system in a real-world environment and acting towards a common or shared goal.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors, Other (Robotics)

KEYWORDS: Robotics, Multiple Robots, Sensor Fusion, Battlefield Reconnaissance

INTEGRATING DIGITAL SIGNAL COLLECTION AND PROCESSING INTO THE SH-60R NAVAL AIR MULTI-PURPOSE PLATFORM (U)

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Master of Science in Electrical Engineering-September 1998
Advisors: Vicente C. Garcia, Jr., National Security Agency Cryptologic Chair
Herschel H. Loomis, Jr., Department of Electrical and Computer Engineering

The capability of the SH-60R helicopter to become a BGPHES platform combined with other IO capabilities is not planned at this time. The primary station for this aircraft will be approximately 200 nautical miles from the carrier and this position presents an opportunity for gathering intelligence. The SH-60R also possesses a unique capability in that it can relay communications and data directly to a ship via secure link. This thesis explores the possibility of incorporating a new architecture that could be adaptable for several mission scenarios. Signal processing necessary to support mission scenarios is introduced which could be incorporated into IW tactics. This thesis will begin by introducing the reader to the SH-60R aircraft and specific signal processing software. The reader will then be introduced to real world signals and the exploitation of them.

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Computing and Software, Electronic Warfare

KEYWORDS: Digital, SH-60R, ELINT, COMINT, SIGINT, MARTES

ANALYSIS OF REAL TIME EMITTER LOCATION ALGORITHMS FOR TACTICAL ELECTRONIC WARFARE AIRCRAFT

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Second Reader: Harold A. Titus, Department of Electrical and Computer Engineering

Geographic location of radar emitters is the process of estimating an emitter's location upon the surface of the earth from direction of arrival (DOA) data for the targeted emitter. The current Emitter Location (EMLOC) algorithm utilized by the Grumman EA-6B Prowler is based on a thesis presented by Mr. Richard Opperman in June 1982. With the advent of increased processing demands on the AN/AYK-14 Tactical Computer as part of recent software upgrades to the AN/ALQ-99 Tactical Jamming System, it was hoped that a Kalman Filter, or Extended Kalman Filter based algorithm, would reduce the processing time and memory requirements for the EMLOC algorithm. This thesis compares the current algorithm and the Kalman/Extended Kalman Filters in a tactical scenario to determine if a change in the current Onboard Flight Program (OFP) should be recommended.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Kalman Filter, Extended Kalman Filter, Location Algorithm

INTEGRATING DIGITAL SIGNAL COLLECTION AND PROCESSING INTO THE EP-3E AND P-3C NAVAL AIR RECONNAISSANCE PLATFORMS (U)

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and
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Herschel L. Loomis, Jr., Department of Electrical and Computer Engineering

Abstract is classified

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Space Vehicles, Battlespace Environments, Command, Control and Communications, Computing and Software, Electronics, Electronic Warfare, Human System Interface, Manpower, Personnel, and Training, Sensors, Manufacturing Science and Technology, Modeling and Simulation

KEYWORDS: MARTES, PAT, EP-3E, P-3C, SIGINT, COMINT, ELINT, Digital

ANALYSIS AND DESIGN OF RETROREFLECTORS

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The enhancement of the radar cross section (RCS) of specific bodies above their normal cross section has several military and civilian applications (e.g., sailboats and decoys). This enhancement is achieved by the use of retroreflectors. Retroreflectors are simple geometric conducting structures that concentrate the reflected wave back in the direction of incidence. They are capable of producing a high RCS over a wide range of aspect angles.

This thesis examines the RCS performance of various common retroreflector geometries. The study is performed using two computational electromagnetic simulation codes: a method of moments code and a physical optics code. The contour plots of RCS are presented for different geometries as a function of frequency. For retroreflectors composed of flat plates, the plate shape is varied to determine the affect of the plate size and profile on the RCS.

KEYWORDS: RCS, Retroreflector

DoD KEY TECHNOLOGY AREA: Electronic Warfare

DEVELOPMENT OF A NARROWBAND ZOOM PROCESSING CAPABILITY USING COMMERCIAL PROCESSORS

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This work is part of an ongoing effort to integrate the separate BEARTRAP post mission analysis tools into a system residing in a Microsoft Windows environment. This new integrated system will contain software modules designed to replace the array of diverse processing systems currently being used for BEARTRAP post mission analysis. This thesis develops the module responsible for narrowband zoom processing. This module allows an operator to view high resolution frequency domain data from various sensors using heterodyning and decimation techniques with processing performed by either a desktop personal computer processor or commercial digital signal processing boards. This work presents the development of the narrowband bandwidth determination and decimation sequence algorithms, the development of the heterodyning and narrowband processing using Microsoft Visual C++ as the implementation language, and the testing of the various parts of the Narrrowband Pretrack module in a stand-alone Microsoft Windows application.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Sensors

KEYWORDS: DSP, Narrowband, BEARTRAP

INTEGRATING DIGITAL SIGNAL COLLECTION AND PROCESSING INTO THE EP-3E AND P-3C NAVAL AIR RECONNAISSANCE PLATFORMS (U)

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Abstract is Classified

DoD KEY TECHNOLOGY AREAS: Air Vehicles, Space Vehicles, Battlespace Environments, Command, Control and Communications, Computing and Software, Electronics, Electronic Warfare, Human System Interface, Manpower, Personnel, and Training, Sensors, Manufacturing Science and Technology, Modeling and Simulation

KEYWORDS: MARTES, PAT, EP-3E, P-3C, SIGINT, COMINT, ELINT, Digital

CALIBRATION AND EVALUATION OF WATER SPEED INDICATOR AND COMPASS FOR THE SMALL AUTONOMOUS UNDERWATER VEHICLE NAVIGATION FILTER

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Second Reader: Eric Bachmann, Department of Computer Science

There are three major thrusts to this thesis. The first was to design and build a device to measure ground speed for testing the position estimating capabilities of the Small Autonomous Navigation System (SANS) filter. The ground tests consisted by placing the SANS unit on a golf cart and maneuvering it along a known track. The speed sensing device uses a bicycle wheel attached to the golf cart along with an appropriate time to speed software conversion.

The next problem was to determine if the existing paddle wheel in use would be accurate enough for the SANS to conduct underway tests. To perform this, a mechanism had to be built to channel water and measure its speed while allowing the paddle wheel to be in the flow.

Finally, the electronic compass was found to have heading dependent errors, thus a test was designed to determine its deviation. This was performed by swinging the compass using a transit aligned with its axis. This established a deviation table that was inserted into the SANS code, further refining its directional capabilities.

As a final test for determining the effectiveness of the calibrated inputs, tests were conducted that showed that the SANS filter is capable of obtaining 3 meter accuracy with no Global Positioning Update for an excess of two minutes. This is well beyond the initial goals set for the system.

KEYWORDS: Small Autonomous Navigation System, SANS, Global Positioning

DoD KEY TECHNOLOGY AREAS: Electronics, Sensors, Modeling and Simulation

PERFORMANCE ANALYSIS OF NONCOHERENT BINARY FREQUENCY SHIFT KEYING USING EQUAL GAIN COMBINING AND POST DETECTION SELECTION COMBINING OVER A NAKAGAMI FADING CHANNEL

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Ralph D. Hippenstiel, Department of Electrical and Computer Engineering

In this thesis, the performance of a noncoherent Binary Frequency Shift Keying (BFSK) receiver using Equal Gain Combining (EGC) and Post Detection Selection Combining (PDSC) techniques over a frequency nonselective and slowly Nakagami fading channel is investigated.

Analytical and numerical results obtained for EGC are compared to those obtained for first order PDSC (PDSC-1), second order PDSC (PDSC-2), and third order PDSC (PDSC-3).

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Nakagami Fading Channel, Diversity Combining Techniques, Equal Gain Combining (EGC), Post Detection Selection Combining (PDSC)

INVESTIGATION OF HIGH FREQUENCY SHIP RADAR CROSS SECTION REDUCTION BY MEANS OF SHAPING

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Master of Science in Electrical Engineering-September 1998
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The objective of this thesis is to investigate and evaluate the effectiveness of ship radar cross section (RCS) reduction in the high frequency (HF) band by means of shaping. The study is based on a computer simulation which uses the method-of-moments to compute the RCS of a number of conventional and shaped ship geometries. It was found that a ship with canted deckhouse walls and a standard hull had little reduction in RCS relative to a conventional ship. This result shows that shaping is not as effective at these frequencies (3-30 MHz) as it is in the optical region. The hull is the major contributor to RCS near broadside. Shaping the hull did reduce the RCS slightly for the frequencies and elevation angles investigated.

DoD KEY TECHNOLOGY AREAS: Electronics, Sensors, Surface/Under Surface Vehicles-Ships and Watercraft, Modeling and Simulation

KEYWORDS: HF Radar, Ship, RCS, Method-of-Moments, CAD

RADAR TRANSMITTER IDENTIFICATION VIA SINGLE PULSE ANALYSIS

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This dissertation proposes an entirely new method for the identification of radar transmitters based solely on a single received pulse. The method for building a mathematical model to describe a radar transmitter is discussed in full detail. Also detailed is the method for comparing these models to received radar pulses of unknown source, to determine the best match and therefore identify the source transmitter. The results of using this method on actual radar data are quite good; indeed, this method can even distinguish between different transmitters of the same make, model, and specifications.

The theoretical limits of radar transmitter identification are also explored. Specifically, a new lower bound on the optimum probability of error, applicable to any hypothesis-testing problem, is developed. This bound is applied to the radar case to give an indication of the theoretical limits of transmitter identification that cannot be exceeded.

KEYWORDS: Radar Transmitter Identification, Vector Quantization, Hidden Markov Models, Unintentional Modulation on Pulse, Specific Emmiter Identification

DoD KEY TECHNOLOGY AREAS: Sensors, Modeling and Simulation

MATLAB IMPLEMENTATION OF A FOURIER APPROACH TO OPTICAL WAVE PROPAGATION

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Second Reader: Ron J. Pieper, Department of Electrical and Computer Engineering

This thesis explores a MATLAB implementation of a Fourier transform approach to model and predict transient optical wave propagation through free-space. A three-step approach is adopted in this study. First, the mathematical development establishes the importance of the total impulse response as the Green's function, meeting the boundary conditions and solving the wave equation. Second, a MATLAB program is developed to simulate the mathematical model by computing and displaying the graphical representation of an optical wave's spatial distribution on a plane at a given distance from a spatially filtered source. Third, a circular excitation function is used to verify the program and then the results of another three excitations, namely the square, circularly truncated Gaussian and circularly truncated Bessel functions are similarly generated. The effort of this thesis provides an inexpensive means to analyze a transient optical wave propagation of a spatially filtered optical source.

DoD KEY TECHNOLOGY AREAS: Modeling and Simulation, Computing and Software

KEYWORDS: Green's Function, Spatial Impulse Response, Diffraction, MATLAB

IMPLEMENTATION AND EVALUATION OF AN INERTIAL NAVIGATION SYSTEM (INS) FOR THE SHEPHERD ROTARY VEHICLE

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An autonomous vehicle must be able to determine its global position even in the absence of external information input. To obtain reliable position information, this would require the integration of multiple navigation sensors and the optimal fusion of the navigation data provided by them.

The approach taken in this thesis was to implement two navigation sensors for a four-wheel drive and steer autonomous vehicle: An inertial measurement unit providing linear acceleration in three dimensions and angular velocity for the vehicle's global motion and shaft encoders providing local motion parameters. An inertial measurement unit is integrated with the Shepherd mobile robot and data acquisition and processing software is developed. Position estimation based on shaft encoder readings is implemented. The framework for future analysis including most general motion profiles have been laid.

The sensor's system performance was evaluated using three different linear motion profiles. Test results indicate that the shaft encoder provide a positioning accuracy better than 99% (typ. 7.5 mm for 1 m motion) under no slip conditions for pure translational motion. The IMU still requires further improvement to allow for both sensors to be combined to an integrated system.

KEYWORDS: Robotics, Sensors, Navigation, NPS, Shepherd, Rotary Vehicle

DoD KEY TECHNOLOGY AREAS: Sensors, Ground Vehicles

COMPARISON OF SUPER RESOLUTION ALGORITHMS WITH DIFFERENT ARRAY GEOMETRIES FOR RADIO DIRECTION FINDING

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The objective of this thesis is to investigate and evaluate the effectiveness of modern estimation methods with different array geometries as they apply to the problem of bearing estimation. These algorithms were selected from those that apply to the multidimensional case, including MUSIC, PHD, minimum norm, and Capon's beam-former. These four techniques are chosen based on their high resolution capability, and their ability to deal with three-dimensional non-uniform arrays and can estimate both azimuth and elevation angle of arrival(AOA). Computer simulations were run for linear arrays, circular arrays, and combinations of the two. The test conditions included: (1) two closely spaced emitters and (2) various levels of additive white Gaussian noise.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors

KEYWORDS: Direction Finding, Antenna Array, Superresolution Techniques

DESIGN OF A MICROELECTRONIC CONTROLLER WITH A MIL-STD-1553 BUS INTERFACE FOR THE TACTILE SITUATION AWARENESS SYSTEM

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Spatial Disorientation (SD) is a triservice aviation problem that costs the Department of Defense more than $300 million annually in destroyed aircraft and is the primary cause of pilot-related mishaps in the Navy and the Air Force. As one solution to the SD problem, the Naval Aerospace Medical Research Laboratory has developed the Tactile Situation Awareness System (TSAS). The primary objective of TSAS is to enhance pilot performance and reduce SD-related aircrew/aircraft losses by providing continuous non-visual information using the normally underutilized sensory channel of touch. Using vibrotactile stimulators, TSAS applies information taken from the aircraft's instruments to the pilot's torso. The current implementation of TSAS is a research system that is not compatible with the crowded cockpit of modern aircraft. This thesis presents a design of a microelectronic controller for TSAS compatible with tactical environments. This new system, called the Tactor Interface Microcontroller System (TIMS), incorporates the functionality of the research TSAS into a palm-sized microcontroller system and enables TSAS to communicate directly to the computerized sensory and weapons systems in combat aircraft such as the Navy F/A-18. TIMS brings the TSAS prototype out of the research stage and puts this exciting technology into the hands of the warfighter.

DoD KEY TECHNOLOGY AREAS: Electronics, Human Systems Interface

KEYWORDS: Electronics, Human Systems Interface, TSAS, Embedded System

PERFORMANCE ANALYSIS OF NONCOHERENT DIFFERENTIAL PHASE SHIFT KEYED WITH VARIOUS DIVERSITY COMBINING TECHNIQUES OVER A RICIAN FADING CHANNEL

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The error probability analysis of a noncoherent differential phase shift keyed (DPSK) receiver employing diversity combining techniques is performed. It is assumed that the system operates over a frequency non-selective, slowly fading Rician channel.

This thesis analyzes equal gain combining (EGC), selection combining (SC) and post detection selection combining (PDSC). The first two diversity combining techniques are widely used in communication systems, while PDSC is a new technique. Previous analysis of the EGG and the SC techniques shows that the EGC technique has a better performance than the SC technique in a Rayleigh fading channel. In this thesis, the effect on the performance of a noncoherent DPSK receiver using the diversity combining techniques for Rician fading is examined. It is shown that the PDSC technique provides a performance that is better than the SC but worse than the EGC technique. The PDSC technique allows a relatively simple receiver structure independent of the number of diversity branches.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Rician Fading Channel, Diversity Combining Techniques, Equal Gain Combining (EGG), Selection Combining (SC), Post Detection Selection Combining (PDSC).

DEVELOPMENT OF AN ACOUSTIC TRANSIENT ANALYSIS USER INTERFACE FOR DETECTION AND TARGET LOCALIZATION

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Advisor: Charles W. Therrien, Department of Electrical and Computer Engineering
Second Reader: Michael K. Shields, Department of Electrical and Computer Engineering

This work is part of an ongoing effort to integrate the separate Beartrap post mission analysis tools into a system residing in a Microsoft Windows environment. This new integrated system will contain software modules designed to replace the array of diverse processing systems currently being used for Beartrap post mission analysis. This thesis develops the module responsible for acoustic transient detection and analysis. This module allows an operator to view time domain data from various sensors, record time of arrival data for a transient, and use the times from various buoys to calculate target position using a Time Difference of Arrival (TDOA) algorithm. The algorithm provides a closed form solution of target position and transmission time based on Time Difference of Arrival data. The accuracy of this solution depends on the accuracy of the time of arrival measurements, the accuracy of the sensor positions, and the sensor geometry. This work presents the development of the user interface using Microsoft Visual C++ as the implementation language, the development of the TDOA algorithm, and the testing of the various parts of the Transient Analysis module in a stand-alone Windows 95 application.

KEYWORDS: Transient, TDOA, Beartrap

DoD KEY TECHNOLOGY AREAS: Computing and Software, Sensors

ESTIMATING THE ACOUSTIC MODAL ARRIVALS USING SIGNALS TRANSMITTED FROM TWO SOUND SOURCES TO A VERTICAL LINE HYDROPHONE ARRAY IN THE 1996 SHELFBREAK PRIMER EXPERIMENT

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Charles Therrien, Department of Electrical and Computer Engineering

During the 1996 multi-institutional Shelfbreak PRIMER experiment, low frequency sound sources were moored on the continental slope south of Cape Cod. These sources transmitted phase encoded tomography signals which were monitored by vertical-line hydrophone arrays moored on the continental shelf. The measured signals were processed for the acoustic modal arrivals and their variability in time. The processing entailed pulse compression, coherent averaging, local sound-speed profile updates and an application of the Chiu-Miller-Lynch model-based modal beamforming technique. In this thesis, the signal processing procedure is discussed and the modal arrival estimates are examined. The model-based estimates are found to be of high quality, with all propagating modes individually resolved. This unambiguous separation of the high modes cannot be achieved using simple least-squares techniques because of under sampling. The temporal variability of the modal amplitudes and travel times are found to be related to ocean processes that are unique to the shelf-slope littoral environment.

DoD KEY TECHNOLOGY AREAS: Battlespace Environments, Sensors

KEYWORDS: Acoustics, Array, Mode, Processing

AN OPERATIONAL HIGH POWER MICROWAVE APPLICATION FOR INFORMATION OPERATIONS (U)

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and
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This thesis documents the results of a feasibility demonstration of a high power microwave application for Information Operations and recommends future improvements to the system. Success in the Information Operations (IO) and Information Warfare (IW) arena requires advanced capabilities. This thesis describes one such capability that would provide commanders with courses of action previously unavailable.

DoD KEY TECHNOLOGY AREA: Directed Energy Weapons

KEYWORDS: Information Operations, High Power Microwave

DEVELOPMENT OF ANALYSIS TOOLS AND INCORPORATION OF COMMERCIAL DIGITAL SIGNAL PROCESSORS IN A SIGNAL ANALYSIS GRAPHICAL USER INTERFACE

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Electrical Engineer-June 1998
Advisors: Charles W. Therrien, Department of Electrical and Computer Engineering
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This work is part of an ongoing effort to integrate the separate BEARTRAP post mission analysis tools into an application operating in a Microsoft Windows environment. This new integrated system will contain software modules designed to replace the array of diverse processing systems currently being used for BEARTRAP post mission analysis. This thesis develops the module responsible for Fast Time Analysis. This module allows an analyst to generate, display, and analyze broadband and narrowband sonograms collected from a BEARTRAP mission. The overall objective of the module is to quickly identify acoustic events of interest. This document describes the development of the generation and display of broadband and narrowband grams using Microsoft Visual C++ as the implementation language, the development of the tools necessary for gram analysis, the development of a supplemental digital signal processing board for increased computational power, and the testing of the various parts of the Fast Time Analysis module in a standalone Microsoft Windows application.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Sensors

KEYWORDS: DSP, Narrowband, Broadband, BEARTRAP, Graphical User Interface

A CENTRALIZED TIME-SPACE-POSITION INFORMATION ARCHITECTURE FOR ABSOLUTE TARGETING IN HIL CAPTIVE-CARRY MISSILE SIMULATOR EXPERIMENTS (U)

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Second Reader: Al DiMattesa, Naval Research Laboratory

Captive-carry electronic warfare experiments are performed using hardware-in-the-loop (HIL) missile simulators in order to determine the effectiveness of the targeted platform's electronic attack (EA) self-protection system. To determine the EA effectiveness, these experiments require that the position of the captive-carry aircraft and other moving objects on the test range (e.g., chaff) be known precisely as a function of time. Distributed Sensor, Time-Space-Position Information systems have been used to provide this information and typically consist of two or more measurement sensors located at some distance from each other with each sensor making a measurement of the target's angle and range. These systems are very complex since they involve multiple hardware installations, complex mathematical computations for extraction of coordinate information, synchronization of multiple sensor measurements, and independent calibration of several different measurement stations. Consequently, the accuracy of the resolved target positions can be severely degraded. This thesis presents a Centralized Time-Space-Position Information Architecture for Absolute Targeting that accurately displays in geodetic coordinates, a complete pictorial presentation of a field test experiment using only the onboard sensors of the captive-carry aircraft. By successfully synchronizing and integrating data from the Inertial Navigation System (INS), the Global Positioning System (GPS), and the targeting information from several distributed HIL missile simulators, accurate displays of the test range results are provided for easy interpretation and analysis. The architecture presented also provides both manual and automatic tagging routines to analyze and evaluate specific points of interest during a particular field test scenario (e.g., missile transfers lock to decoy). Actual captive-carry field test results using anti-ship cruise missile HIL simulators are presented in order to demonstrate the advantages of this approach.

DoD KEY TECHNOLOGY AREAS: Electronic Warfare, Sensors, Modeling and Simulation

KEYWORDS: Absolute Targeting, ASCM HIL Simulators, Captive-Carry Field Tests, Sensor Synchronization, GPS, INS, Track Tagging

PERFORMANCE ANALYSIS OF DIFFERENTIAL PHASE SHIFT KEYED SIGNALS WITH SELECTION COMBINING AND CONVOLUTIONAL CODING IN FADING CHANNEL

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Ralph D. Hippenstiel, Department of Electrical and Computer Engineering

The performance analysis of a differential phase shift keyed (DPSK) communications system, operating in a Rayleigh fading environment, employing convolutional coding and diversity processing is presented. The receiver is the conventional square-law DPSK receiver using soft-decision convolutional decoding. The computationally efficient union bound technique is utilized to evaluate the system performance.

The coded and uncoded system performances of various diversity combining techniques are evaluated and compared. The combining techniques considered include equal gain combining (EGC), selection combining (SC), and a generalization of SC, whereby two or three signals with the two or three largest amplitudes are noncoherently combined. This generalized method is called second or third order SC and denoted as SC2 or SC3, respectively. Numerical results indicate that coded systems with SC2 and SC3 techniques significantly enhance the bit-error rate (BER) performance relative to that achievable with SC.

DoD KEY TECHNOLOGY AREA: Command, Control and Communications

KEYWORDS: Diversity, Convolutional Coding, Decision Decoding, Rayleigh Fading, Numerical Analysis

AN ANALYSIS OF A BROADBAND MULTI-CARRIER CODE DIVISION MULTIPLE ACCESS (CDMA) CELLULAR COMMUNICATIONS SYSTEM

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R. Clark Robertson, Department of Electrical and Computer Engineering

The integration of land, sea, and air forces within the littoral environment will require fading resistant, high data rate, non-exploitable communications. The large volumes of video and data information, i.e. Internet access, video teleconferencing, and data transfer, required to support the war fighter within a Joint Task Force demands technologies that reduce the interference imposed by poor terrestrial and atmospheric conditions. In order to minimize the effect of frequency-selective fading that occurs in these conditions and to provide high data rate communications, this thesis presents the analysis of a broadband cellular system featuring a multicarrier, code division multiple access (CDMA) method. The system designed complies with Federal Communication Commission broadband cellular standards and uses CDMA to reduce the probabilities of detection and interception as well as providing for multiple access, which in conjunction with the multicarrier approach enables on demand access to high data rate communications.

DoD KEY TECHNOLOGY AREAS: Command, Control, and Communications, Modeling and Simulation

KEYWORDS: Littoral Communications, Analysis, Cellular, CDMA, Broadband, Multicarrier

PERFORMANCE ANALYSIS OF BINARY FSK SIGNALS WITH L-FOLD DIVERSITY SELECTION COMBINING TECHNIQUES IN A NAKAGAMI-M FADING CHANNEL

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This thesis investigates the performance analysis of a non-coherent Binary Frequency Shift Keying (BFSK) receiver using Selection Combining techniques over a frequency non-selective, slowly fading Nakagami channel. These techniques are independent of the number of diversity branches, so simpler receivers can be employed.

First order selection Combining (SC), second order Selection Combining (SC-2), and third order Selection Combining (SC-3) techniques are evaluated and compared to each other. Numerical results show that the performance improves as the order of Selection Combining techniques increases.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Nakagami –M Fading Channel, Diversity Combining Techniques, Selection Combining (SC)

ROBOTIC MANIPULATION ON A MOVING PLATFORM UTILIZING FORCE SENSING AND SONAR RANGING

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Robotic manipulators are widely used in industry where the environment may be too hostile for workers. However, their application has been limited to an industrial setting where the robot is mounted on a stationary base. It is of great interest to expand the application of the robot manipulator to where it is mounted on an autonomous delivery vehicle. This application would enable the delivery vehicle not only to locate objects in a hostile environment, but also to perform tasks that would entirely remove the human being from the hostile environment. This thesis explores the feasibility of implementing a manipulator on an autonomous vehicle. A Zebra-ZERO Force Control Robot is mounted on a moving platform for feasibility simulations of an autonomous delivery vehicle. The Zebra-ZERO system consists primarily of a robotic arm with six degrees of freedom, a six-axis force sensor mounted at the end of the manipulator, and supporting computer hardware and software. In this thesis, the capability of the Zebra-ZERO system is expanded by integrating it with an external sonar ranging system. The sonar ranging system provides range feedback that is critical for positioning the manipulator while it is mounted on a moving platform. Test results demonstrate that the manipulator mounted on a moving platform is able to compensate for random platform motions and successfully perform various manipulation tasks.

DoD KEY TECHNOLOGY AREA: (Other Robotics)

KEYWORDS: Control, Zebra-ZERO, Force Sensor, Sonar Ranging, Robot Manipulator

FREQUENCY REUSE THROUGH RADIO FREQUENCY (RF) POWER MANAGEMENT IN SHIP-TO-SHIP DATA NETWORKS

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A proposed U.S. Navy ship-to-ship, line-of-sight, high-data-rate communication system is analyzed. Because of the limited bandwidth available in the UHF band, it is desired to reuse a frequency channel at the shortest possible range. By limiting the radiated power to the minimum required to establish a desired quality of service, the channel can be reused at considerably shorter ranges than when the transmitter output power is fixed to the maximum available. Frequency reuse, however, introduces the problem of cochannel interference which degrades system performance.

A computer simulation was developed to determine the bit error rate (BER) of a QPSK system in a Ricean fading channel with one cochannel interferer. The simulation generates plots of energy per bit to one-sided noise power spectral density ratio $(E_b IN_o)$ versus BER. Simulation results are used to compute the minimum range (R) at which the channel can be reused while maintaining an average BER of 10^{-6}. The results show that even when no power control is used the channel can be reused at a range, R, of approximately 45 kilometers. This range can be reduced to less than 20 kilometers if an interfering ship can reduce its output power by 30 dB.

KEYWORDS: Radiated Power Control, Frequency Reuse, Cochannel Interference, Ship-to-Ship Data Networks, Reuse Range, QPSK, BER, Fading Channel

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

OPNET IMPLEMENTATION OF SPREAD SPECTRUM NETWORK FOR VOICE AND DATA DISTRIBUTION

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Tri Ha, Department of Electrical and Computer Engineering

This thesis presents an OPNET model and simulation of a single cell wireless communications system within a proposed expeditionary warfare communications network. The focus of this thesis is to model and implement data and voice traffic generation, slotted ALOHA medium access control protocol, and direct sequence spread spectrum code division multiple access (CDMA) mechanisms in OPNET. The RF channel is modeled as both a Rayleigh fading channel and a non-fading noise limited channel. Simulation results evaluating the induced BER and multiple access implementation are presented.

KEYWORDS: OPNET, CDMA, Spread Spectrum, Slotted ALOHA, Medium Access Control, Expeditionary Warfare Communications

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

THEATER BALLISTIC MISSILE DEFENSE–MULTISENSOR FUSION, TARGETING, AND TRACKING TECHNIQUES

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The Gulf War illustrated how important ballistic missile defenses have become to the United States. The study of intercepting Theatre Ballistic Missiles (TBMs) in their boost phase was prompted by concerns about the widespread dissemination of submunitions and the differentiation of decoys from actual warheads released early in the missile's midcourse flight. Boost Phase Intercept (BPI) would alleviate this problem by destroying the enemy's ballistic missile in the missile's launch phase, thereby causing the lethal payload and debris from the engagement to fall back on the aggressor. This thesis focuses on the development of missile tracking algorithms to be used in the boost phase of TBMs. A missile encounters significant changes in velocity, acceleration, and direction during the boost phase, making it difficult to track. Extended Kalman filter (EKF), Alpha-Beta-Gamma filter, and Interacting Multiple Model (IMM) filtering techniques are developed to determine the missile tracking accuracy of TBMs during boost phase. Simulation results and actual TBM profiles from test data are presented to verify the tracking accuracy utilizing different filtering techniques.

DoD KEY TECHNOLOGY AREA: Modeling and Simulation

KEYWORDS: Kalman Filter, Alpha-Beta-Gamma Filter, Interacting Multiple Models, Theater Ballistic Missile Defense

DESIGN, CONSTRUCTION AND TESTING OF AN AUTONOMOUS MINE HUNTER

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Landmine detection is an immense technological problem. A small, low power metal detector would find application in concert with other search technologies. A detection circuit was designed and constructed consisting of a search coil and a CMOS exclusive OR gate forming an oscillator. This was interfaced to a microprocessor which counted the pulses from the oscillator and decided whether a detection had been made. Detection range for an anti-personnel mine like object was 14 cm at the coil centerline. A robot platform to autonomously search for landmines was constructed.

KEYWORDS: Landmine, Induction, Robot, Microprocessor

DoD KEY TECHNOLOGY AREA: Sensors

REFRACTIVE CONDITION IN THE CARIBBEAN SEA AND ITS EFFECT ON RADAR SYSTEMS

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Vertical gradients of pressure, temperature and humidity of the troposphere exert a strong influence over propagation of VHF, UHF, and SHF frequencies. These frequencies are associated with aircraft communications, radars and satellite communications, so it is important in military operations to collect precise and timely data from atmospheric conditions.

In this thesis programs from EREPS were used to assess refractive conditions in the Caribbean Sea against selected radar systems. Data given by SDS from radiosonde stations located in MS 43 and 44 were used as input for COVER and PROPR programs. Outputs from COVER are analyzed to find Optimal Altitude to Avoid Detection (OAAD) for a low-flying target. Outputs from PROPR using climatological data given by SDS and Optimal Altitude to Avoid Detection from COVER was used to verify OAAD against selected land- and ship-mounted radars operating in the Caribbean Sea. Finally, a system under development, TDROP is introduced in response to requirements for timely and exact data, in order to enhance the tactical data collection process.

DoD KEY TECHNOLOGY AREA: Electronic Warfare

KEYWORDS: Refractive Conditions, Air Defense, Radar Systems

LOW LATITUDE IONOSPHERIC EFFECTS ON RADIOWAVE PROPAGATION
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Jeffrey B. Knorr, Department of Electrical and Computer Engineering
Wilbur R. Vincent, Department of Electrical and Computer Engineering
David D. Cleary, Department of Physics
Kenneth L. Davidson, Department of Meteorology

This dissertation provides experimental observations and analyses that associate low-latitude transionospheric signal scintillation with transequatorial VHF radio propagation and errors in transionospheric geopositioning.

The experiment observed equatorial-region ionospheric total electron content (TEC) derived from Global Positioning System (GPS) signals using receivers on Oahu, Hawaii, Christmas Island, and Rarotonga, Cook Islands. The experiment simultaneously measured VHF transequatorial propagation of VHF television signals from Hawaii to Rarotonga.

Analysis shows that a moving second moment of vertical-equivalent TEC strongly correlates to each VHF transequatorial radio propagation event. From experimental observation analysis, the author develops models for prediction of TEP and time-space distribution of low-latitude transionospheric scintillation.

The author also develops equations that show the potential errors in time, frequency, and angle used in geopositioning solutions. These three parameters are potentially correctable using these techniques.

DoD KEY TECHNOLOGY AREA: Sensors

KEYWORDS: Low-Latitude, Ionosphere, Equatorial, Scintillation, Geopositioning, Global Positioning System, GPS, Total Electron Content, TEC, Transequatorial Propagation, TEP

IT-21 COMPLIANT CONTROLLED ACCESS TO INTERNET WEB PAGES
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Master of Science in Systems Engineering-September 1998
Advisor: Gus K. Lott, Department of Electrical and Computer Engineering
Second Reader: Daniel F. Warren, Department of Computer Science

Although numerous resources are available to achieve Internet presence by creating and publishing a web site, security and access control within the site are very limited. The Navy's support of the IT-21 initiative embracing the Microsoft®

Windows NT® operating system (OS) provides solutions to not only restrict entry to the site, but also to control access to content on the web page.

Work detailed in this thesis addresses the issue of security by exploring the Windows NT OS and activating its inherent security features to protect the overall system from intrusion and attacks from the Internet. The web pages are published using Microsoft® Internet Information Server 4.0 (IIS) and FrontPage™ 98. Access is controlled by issuing certificates from the resident Microsoft® certificate Server software package or remotely by VeriSign™ OnSite service. Windows NT and IIS permit a certificate to be mapped to a system account to further define the level of access assigned to each user down to the file level.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Electronic Warfare

KEYWORDS: IT-21, Microsoft Windows NT, Microsoft Internet Information Server, Certificates

DETECTION AND CLASSIFICATION OF DIGITAL COMMUNICATION SIGNALS USING SECOND- AND HIGHER-ORDER CYCLOSTATIONARY FEATURES (PART I/II) (U)

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Conventional detection and classification techniques with regards to digital communications rely primarily on one or a combination of the following: Knowledge that a single known signal is present or absent, a *priori* knowledge of modulation parameters of multiple possible signals; energy or power measurements; temporal or spectral feature measurement. Though these techniques are successful in many instances, they are severely limited in significant additive white Gaussian noise (AWGN) and co-channel interference. By processing the signals as cyclostationary, a new set of features can be obtained that remain uniquely identifiable in the presence of strong noise and other signals. Two such signal processing approaches are tested here. The Automatic Signal Classifier (ASC) exploits second-order cyclostationarity via the spectral correlation function (SCF), while higher-order cyclostationarity (HOCS) is exploited via the temporal cumulant function (TCF) in the HOCS-Based Classifier (HBC). These detection and classification algorithms demonstrate a signal-selectivity property that renders them inherently more tolerant to noise and interference in a series of tests conducted first with simulated digital communications and secondly with actual transmitted digital communications.

DoD KEY TECHNOLOGY AREAS: Command, Control and Communications, Sensors

KEYWORDS: SIGINT, Signal Processing, Cyclostationary, Spectral Correlation, Temporal Cumulants

AUDITORY-VISUAL CROSS-MODAL PERCEPTION PHENOMENA

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The quality of realism in virtual environments is typically considered to be a function of visual and audio fidelity mutually exclusive of each other. However, the virtual environment participant, being human, is multi-modal by nature. Therefore, in order to more accurately validate the levels of auditory and visual fidelity required in a virtual environment, a better understanding is needed of the intersensory or cross-modal effects between the auditory and visual sense modalities.

To identify whether any pertinent auditory-visual cross-modal perception phenomena exist, 108 subjects participated in three main experiments which were completely automated using HTML, Java, and JavaScript computer programming languages. Visual and auditory display quality perception were measured intramodally and intermodally by manipulating visual display pixel resolution and Gaussian white noise level and by manipulating auditory display sampling frequency and Gaussian white noise level.

Statistically significant results indicate that 1) medium or high-quality auditory displays coupled with high-quality visual displays increase the quality perception of the visual displays relative to the evaluation of the visual display alone, and 2) low-quality auditory displays coupled with high-quality visual displays decrease the quality perception of the auditory displays relative to the evaluation of the auditory display alone. These findings strongly suggest that the quality of realism in virtual environments must be a function of both auditory and visual display fidelities inclusive of each other.

DoD KEY TECHNOLOGY AREAS: Computing and Software, Human Systems Interface, Modeling and Simulation

KEYWORDS: Virtual Environment, Auditory Display, Visual Display, Perception, Cross Modal, Fidelity, Experimental Design

A WIDEBAND MULTICARRIER CODE DIVISION MULTIPLE ACCESS (CDMA) CELLULAR COMMUNICATIONS SYSTEM

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Second Reader: R. Clark Robertson, Department of Electrical and Computer Engineering

The demand for mobile access to high data rate communications services such as video teleconferencing, Internet access, or file transfer continues to grow rapidly for a wide variety of military as well as commercial applications. Existing mobile narrowband cellular communications systems do not have sufficient bandwidth to support high data rate applications. Simply increasing the bandwidth of existing cellular systems to support higher data rates results in a significant degradation in signal quality and reliability due to frequency selective fading. The wideband cellular system design presented in this thesis features a multicarrier approach that minimizes frequency selective fading for very high data rate applications and a dual mode reverse channel that facilitates efficient utilization of bandwidth for low to very high data rate applications.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Cellular, CDMA, Wideband, Multicarrier

PERFORMANCE ANALYSIS OF NONCOHERENT DIFFERENTIAL PHASE SHIFT KEYINGUSING POST-DETECTION SELECTION COMBINING OVER A RAYLEIGH FADING CHANNEL
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Ralph D. Hippenstiel, Department of Electrical and Computer Engineering

In this thesis, the performance analysis of a noncoherent Differential Phase Shift Keying (DPSK) receiver using Post-Detection Selection Combining techniques over a Rayleigh fading channel is investigated. Post-Detection Selection Combining (PDSC) is evaluated and compared to Equal Gain Combining (EGC) and Selection Combining (SC), the two common diversity techniques discussed in the literature. Numerical results obtained for Post-Detection Selection Combining are compared to Selection Combining and Equal Gain Combining. The Post-Detection Selection Combining method is shown to be superior to the Selection Combining method but inferior to Equal Gain Combining method for a non-coherent DPSK receiver operating over a Rayleigh fading channel.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Rayleigh Fading Channel, Diversity Combining Techniques, Equal Gain Combining (EGC), Selection Combining (SC), Post-Detection Selection Combining (PDSC)

PERFORMANCE ANALYSIS OF A SLOW FREQUENCY HOPPED, NONCOHERENT BINARY FREQUENCY-SHIFT KEYING COMMUNICATION SYSTEM WITH RATE 1/2 CONVOLUTIONAL CODING AND SOFT DECISION VITERBI DETECTION OVER A RICEAN FADING CHANNEL WITH PARTIAL-BAND NOISE JAMMING
Thomas W. Tedesso-Lieutenant, United States Navy
B.S.E.E, Illinois Institute of Technology, May 1990
Master of Science in Electrical Engineering-March 1998
Advisor: R. Clark Robertson, Department of Electrical and Computer Engineering
Second Reader: Tri T. Ha, Department of Electrical and Computer Engineering

A performance analysis of a slow frequency-hopped, noncoherent binary frequency-shift keying (SFH/NCBFSK) communication system with rate 1/2 convolutional coding and soft decision Viterbi detection in the presence of partial-band noise jamming is performed. The effect of additive white Gaussian noise is also considered. The analysis is performed for both a non-fading channel and a Ricean fading channel. The system's performance is severely degraded by partial-band noise jamming. By way of comparison the analysis is also performed when the system utilizes hard decision Viterbi detection and for a system utilizing noise-normalized combining with soft decision Viterbi detection. In both cases a significant increase in the system's immunity to the effects of partial-band noise jamming is achieved.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications

KEYWORDS: Spread Spectrum Communications, Digital Communications, Partial-band Jamming, Fading Channel, Frequency-Hopped Spread Spectrum Communications

CHANNEL ALLOCATION IN WIRELESS INTEGRATED SERVICES NETWORKS FOR LOW-BIT-RATE APPLICATIONS

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Craig W. Rasmussen, Department of Mathematics
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This work addresses issues related to the design and performance of a wireless integrated services network with emphasis on a tactical framework. We propose an asynchronous transfer mode (ATM)-like protocol architecture for the mobile network, which is an extension of schemes proposed in the literature. A medium-access-control (MAC) scheme, based on slot reservation by the remotes, is proposed for the network. Traffic models for low-bit-rate applications, suitable for low-capacity channels, such as a multiple-access (macrocell) wireless network, are presented. New bi-directional speech-conversation and bursty data models are proposed.

The issue of scheduling in wireline integrated services networks is thoroughly addressed and new algorithms are proposed. An analytical scheme to obtain the required (static) capacity for homogeneous sources based on their Markov-chain characterization is provided. A necessary condition for optimality of a scheduling algorithm is the balance of cell-loss-probability (CLP) ratios to values approaching 1 from below, on the boundary of the admissible region. The balanced-CLP-ratio (BCLPR) algorithm satisfies this condition but ignores the deadlines of the cells. The shortest time to extinction (STE) with BCLPR (STEBR) algorithm, proposed here for the first time, utilizes the earliest-deadline-first concept while satisfying the necessary condition. A proof is provided to show that the STEBR decisions are optimal at each service slot given that no information about future traffic arrivals is available. Simulation results indicate that STEBR admits more sources and yields larger normalized channel throughput (by up to 4%) than STE.

The wireless network presents a case of distributed queues at the command post (CP) and in the remotes, making channel allocation more involved compared to scheduling in wireline systems. Based on the schedulers discussed for the wireline queue, corresponding algorithms for operation in the wireless network are developed. The cases of partial and complete status reports of the remotes are investigated as a function of the network load in five representative scenarios. The following (descending) order of performance under both partial and complete status reports is maintained in all scenarios:STEBR, STE, BCLPR, and static allocation. Performance of the schedulers using partial or complete status reports depends on the value of the normalized throughput. The complete-status mechanism is preferred whenever the normalized throughput is smallerthan 0.70-0.75; partial status reports are sufficient for normalized throughput larger than 0.70-0.75. A hybrid approach that makes use of this outcome is proposed to best utilize the available channel capacity under all possible levels of network load.

DoD KEY TECHNOLOGY AREA: Command, Control, and Communications, Modeling and Simulation, Other (Networking)

KEYWORDS: B-ISDN, ATM, MAC, Scheduling, Channel Allocation, Mobile Networks, Low-Bit-Rate Source Models

INTEGRATION OF MARTES AND PAT CRYPTOLOGIC TOOLKITS FOR THE INFORMATION WARRIOR

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Second Reader: Herschel Loomis, Department of Electrical and Computer Engineering

A number of Cryptologic tools have been created over the past two decades to assist in national intelligence gathering tasks. Among the current tools being used to aid NSA Cryptologic efforts are the MARTES and PAT software programs. This

thesis will begin by discussing a need for such software tools in the world today. After examining the MARTES and PAT software toolkits to understand exactly how they perform their respective Cryptologic functions, detailed examples of MARTES and PAT processing and analysis will follow, showing the effectiveness of each program. The final discussion will examine why MARTES should integrate the PAT program into its available toolkits. Logistic and operational issues associated with such an integration will also be explored before recommending future areas of study.

KEYWORDS: MARTES, PAT, TINKERTOY, SIGINT, Cryptology, National Security Agency

DoD KEY TECHNOLOGY AREA: Other (lnformation Operations)

THE VLSI IMPLEMENTATION OF A GENERALIZED IMMITTANCE CONVERTER SWITCHED CAPACITOR FILTER

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In this research, the design and VLSI implementation of a digitally programmable active analog filter, based on the Generalized Immittance Converter (GIC) circuit, are presented. The programmable features include the filter type (band-pass, high-pass, low-pass or notch), the center or cut-off frequency, and the quality factor. Switched capacitor networks are used to implement resistances. The design was first simulated and then implemented on a wire-wrap board and tested. The circuit was then modeled and re-simulated using the Cadence Design Tools software package. Once the modeled circuit passes all design rule checks the final chip design was then submitted for fabrication. This research project will help provide a knowledge base for using Cadence software for VLSI CMOS design. Once the chip has been fabricated and tested it will provide a base for further development of stray insensitive VLSI design of analog circuits.

DoD KEY TECHNOLOGY AREA: Electronics

KEYWORDS: Switched Capacitor, Generalized Immittance Converter, VLSI, Cadence

RADAR CROSS SECTION REDUCTION: GEOMETRIC CONTROL OF DISCONTINUITIES USING SERRATED EDGES

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The objective of this thesis is to investigate and evaluate the effectiveness of radar cross section (RCS) reduction by means of the geometric control of discontinuities using serrated edges. Although the use of serrated edges for RCS reduction can be clearly seen on stealth aircraft such as the Northrop B-2, and was mentioned in several papers and references, not much data on the reduction magnitude, the associated geometry, or the design methodology are available in the open literature. Parameters of interest include the number of basic serration cells (triangles) required per wavelength, and the aspect ratio of the triangles that form the zig zags. An infinitely thin metallic plate is considered for the analysis. The RCS of such a plate with serrated edges is computed and compared against the RCS of a plate of the same sized without serrated edges. The infinitely thin assumption is valid if the wing of the aircraft, which is represented by the plate, is thin compared to the wavelength. The results obtained show significant reduction in RCS.

KEYWORDS: Radar Cross Section, Edge Diffraction, Method of Moments

DoD KEY TECHNOLOGY AREA: Electronics

PHOENIX AUTONOMOUS UNDERWATER VEHICLE (AUV):NETWORKED CONTROL OF MULTIPLE ANALOG AND DIGITAL DEVICES USING LONTALK

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The purpose of this thesis is to simplify analog and digital device control inside the *Phoenix* autonomous underwater vehicle (AUV). *Phoenix* is required to process many data information streams associated with a variety of different sensors. Real-time processing is required both for input sensing and for output directing. As presently configured, hardware devices aboard the *Phoenix* are manually connected and configured using parallel ports, serial ports, analog-to-digital (A/D) and digital-to-analog (D/A) controller hardware. Current hardware control within *Phoenix* connects all devices individually to a single computer. This approach is cumbersome, error-prone and does not scale.

This project investigates the feasibility of using Echelon LonWorks hardware and LonTalk protocol as a faster and scalable networked robot control system. LonWorks/LonTalk is a flexible A/D D/A hardware networking technology that provides reliable communication, decentralized topology with no single point of failure, easy extensibility, excellent throughput, and interoperability for a wide variety of hardware.

This project builds and tests a prototype LonTalk network that connects all *Phoenix* devices. This network demonstrates the capability of using LonWorks to control various types of hardware and support rapid component integration onboard the *Phoenix*. Successful demonstration of a LonTalk solution eliminates a critical barrier to *Phoenix* progress and makes robot execution much more robust.

KEYWORDS: Autonomous Underwater Vehicle, AUV, Networked Control, LonWorks Technology, LonTalk, LonBuilder

DoD KEY TECHNOLOGY AREAS: Computing and Software, Surface/Under Surface Vehicles-Ships and Watercraf

A DIGITAL IMAGE SYNTHESIZER FOR INVERSE SYNTHETIC APERTURE RADAR (ISAR) COUNTER-TARGETING

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Inverse Synthetic Aperture Radar (ISAR) is a version of SAR that can be used operationally to image targets such as ships, aircraft, and space objects. It falls under the genre of imaging radars, since an ISAR image contains information on range, cross-range, and reflectivity (radar cross-section) of the target. Active deception, such as the use of false targets, requires special consideration against these types of radars. The purpose of this thesis is to study, design, and develop a hardware "digital image synthesizer" prototype using Field Programmable Gate Arrays (FPGA) capable of producing coherent false target images on such radars. The proposed hardware uses digital tapped-delay lines for time-interval (range gate) generation and the use of Doppler focussing and radar cross-section blocks for frequency and gain modulations respectively. The suite of simulation software, including a bit-and-architecturally true simulator, format conversion files, visual basic program and hardware are developed to demonstrate the concept of the digital image synthesizer. Moreover, the hardware results match those from the bit-and-architecture simulator's results closely.

DoD KEY TECHNOLOGY AREA: Electronic Warfare

KEYWORDS: Inverse Synthetic Aperture Radar, Countermeasure